

July 20–21 Review: Tiling

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1. The Tiling Problem

The Sloan Digital Sky Survey (SDSS; York, *et al.* 2000) consists of an imaging survey of 10,000 square degrees of sky, and a spectroscopic survey of roughly 10^6 targets selected from these images. These targets consist for the most part of galaxies and QSOs; their identification and selection are described elsewhere in this review. Let us simply note here that there are about 120–130 such targets per square degree on average, and that they are not distributed perfectly uniformly across the sky (that is to say, they cluster).

To observe the targets, we use a multi-object fiber spectrograph which has a circular field of view (“tile”) 1.49° in radius and which can observe 592 targets simultaneously (48 more fibers are used to observe the sky as well as standards). An important constraint is that no two fibers on any single tile can be placed closer than $55''$. If two targets happen to be closer than this distance, they are said to “collide.” About 20% of targets collide with one or more other targets. Both targets in such a collision can be observed only if they are in the overlap between two adjacent tiles (about 40% of the sky will be covered by such overlaps). A simple calculation reveals that ~ 2000 tiles are needed to provide fibers for all targets in the survey. Two problems must be solved to make best use of these tiles: first, we must determine how to assign fibers to tiles, given a set of tile centers; second, we must determine the best way of placing the tiles.

First, given a set of tile locations, we must determine the most efficient way to assign fibers to tiles. By expressing the problem as a classic network flow diagram, it turns out to be possible to produce nearly optimal solutions to the fiber assignment problem, even in the presence of fiber collisions. We find our solution in two steps:

- We define a maximal subset of targets which do not collide with each other (the “decollided” targets). We optimally assign fibers to these targets using the network flow. This step ensures that most of the targets which are not assigned fibers are ones which we would have lost due to collisions anyway.
- We then assign fibers for all targets located in the overlaps of tiles, again using a network flow solution. In this case, we construct the network flow such that it finds the best way to assign fibers such that it resolves the greatest possible number of collisions.

Although combining these separate steps into a single one would be the most efficient algorithm possible, the two-step method ensures a well-defined set of “decollided” targets which is easily reproducible by simulations. That is, we will know exactly why we missed any given galaxy: because it collided with another galaxy or because there weren’t enough fibers.

Second, we must determine an efficient placement of the tiles. Because the targets cluster on the sky, a simple uniform covering of the sky is not particularly efficient. Although finding the most efficient tile placement is an *NP*-hard problem, Lupton, Maley, & Young (1996) have developed a heuristic method which is $\sim 20\%$ more efficient than a simple uniform covering. The strategy is based on iterative cost minimization where each iteration consists of two steps:

- “Relaxed Fiber Assignment”: Given a set of tile centers, assign targets to the tiles using the above procedure, but allowing targets outside a tile’s official limits to be assigned to that tile, with an associated cost which increases with radius from the tile center.
- “Tile Perturbation”: Given these assignments, one moves the tile centers to minimize the cost, producing an updated set of tile centers.

Given a uniform initial covering, this algorithm converges to a more efficient covering.

2. Status of the Tiling Implementation

The tiling algorithm as described is completely implemented and was used to place tiles and assign fibers for the spectroscopic observations. The remaining issues, in order of importance, are the following:

- We have not recently tested the algorithm on a distribution of targets which is truly two-dimensional on the sky, only on one-dimensional strips. We are performing such tests using the results of N -body simulations.
- In a related point, we have not worked out how the tiling is going to be run in practice given that SDSS is pipelined. We will not be tiling all 10,000 square degrees at once. On the contrary, as the imaging survey progresses, we will be tiling piecemeal chunks of this area, with as yet unspecified sizes. In particular, we have not yet worked out how to handle galaxies which are missed at the edges of such chunks; naturally, we will need to include them in subsequent tilings of the adjacent chunks, but the best way to do so in practice has not been determined.
- At the moment, the requirement for tiling is that we fail to assign fibers to $< 10^{-2}$ of the “decollided” targets. This requirement can be satisfied with very high efficiency for the one-dimensional strips examined so far. If this remains true for the two-dimensional distributions, we may want to make more stringent requirements. There are two alternatives: decrease the requirement to $< 10^{-3}$ or place a requirement on what percentage of galaxies are lost due to collisions (effectively, how much overlap between tiles there is). Which of these requirements we choose will determine which targets to include in the cost minimization procedure described above. For example, if we decide to require that $< 10^{-3}$ of the decollided galaxies are missed, we will want to determine the tile placement using these galaxies alone.

These issues can be addressed with very little alteration to the code in its present form, and we are in the process of doing so right now.

Thanks to Dan van den Berk, Daniel Eisenstein, Josh Frieman, Ravi Sheth, Michael Strauss, David Weinberg, and Idit Zehavi for useful discussions.

REFERENCES

- Lupton, R. H., Maley, F. M., & Young, N. 1996, 7th Annual SIAM-ACM Proceedings, 296–303
- York, D., *et al.* (2000), submitted to AJ